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[Document Name] SPECIFICATION

[Title of the Invention] LENS, OPTICAL HEAD APPARATUS AND OPTICAL INFORMATION WRITING/READING APPARATUS

[Scope of the Claims]

[Claim 1] A convex lens for allowing luminous flux from a light source to converge to a first optical information recording medium having a predetermined thickness and a second optical information recording medium thicker than the first optical information recording medium, characterized in that said convex lens comprises:

an internal area of the circumference close to a central axis of said luminous flux;

an outer area of the circumference far from said central axis; and

an intermediate area of the circumference located midway between said internal area of the circumference and said outer area of the circumference, and

said internal area of the circumference and said outer area of the circumference are the area where the luminous flux that has passed through said internal area of the circumference or said outer area of the circumference converges onto an information recording surface of said first optical information recording medium,

said intermediate area of the circumference is the area where the luminous flux that has passed through the

intermediate area of the circumference converges at the further place than the information recording surface of said second optical information recording medium.

[Claim 2] A convex lens for allowing luminous flux from a light source to converge to a first optical information recording medium having a predetermined thickness and a second optical information recording medium thicker than the first optical information recording medium, characterized in that said lens comprises:

an internal area of the circumference close to a central axis of said luminous flux;

an outer area of the circumference far from said central axis; and

an intermediate area of the circumference located midway between said internal area of the circumference and said outer area of the circumference, and

said internal area of the circumference, said outer area of the circumference and said intermediate area of the circumference are formed on a surface of said lens, the surface facing said first optical information recording medium or said second optical information recording medium.

[Claim 3] The lens according to claim 2, characterized in that the phase of the luminous flux that has passed through said intermediate area of the circumference is

set to be shifted by substantially 1 wavelength with respect to the phase of the luminous flux that has passed through said outer area of the circumference.

[Claim 4] The lens according to any one of claims 1 to 3, characterized in that the luminous flux that passes through the innermost perimeter of said internal area of the circumference is set to make the phase shifted with respect to the luminous flux that passes through the outermost perimeter of said internal area of the circumference.

[Claim 5] The lens according to claim 4, characterized in that the luminous flux that passes through the innermost perimeter of said intermediate area of the circumference is set to delay with respect to the luminous flux that passes through the outermost perimeter of said internal area of the circumference by an amount Δ that satisfies the following (Equation 1):

Equation 1

$$240° + m \times 360° < \Delta < 360° + n \times 360°$$

m: Integer, n: integer more than or equal to m

[Claim 6] The lens according to claim 5, characterized in that said amount Δ is an amount that satisfies the following (Equation 2):

Equation 2

$$270° + m \times 360° < \Delta < 330° + n \times 360°$$

m: Integer, n: integer more than or equal to m

[Claim 7] The lens according to any one of claims 1 to 6, characterized in that when the numerical aperture (hereinafter referred to as "NA") of all luminous fluxes that have passed through said lens is assumed to be (a), said NA of the boundary between said internal area of the circumference and said intermediate area of the circumference is 0.6(a) to 0.8(a) and said NA of the boundary between said intermediate area of the circumference and said outer area of the circumference is 0.7(a) to 0.9(a).

[Claim 8] The lens according to any one of claims 1, 2, 4, 5, 6 and 7, characterized in that the thickness of said first optical information recording medium is substantially 0.6 mm and the thickness of said second optical information recording medium is substantially 1.2 mm, and

said intermediate area of the circumference is the area where the luminous flux that has passed through the intermediate area of the circumference converges at a farther place than the information recording surface of said second optical information recording medium, 2.2 mm at the farthest.

[Claim 9] An optical head apparatus, characterized by comprising the lens according to any one of claims 1 to

8 and a photoreception element that receives reflected light from said first optical information recording medium or said second optical information recording medium and converts said reflected light to an electric signal.

[Claim 10] An optical information recording medium writing/reading apparatus, characterized by comprising the optical head apparatus according to claim 9 and a circuit that distinguishes said first optical information recording medium from said second optical information recording medium, selectively reads information from said electric signal.

[Claim 11] An optical information recording medium writing/reading apparatus, characterized by using said lens according to any one of claims 1, 2, 4, 5, 6, 7 and 8, wherein the optical information recording medium writing/reading apparatus,

converges luminous flux from a light source onto said first optical information recording medium or said second optical information recording medium,

receives reflected light from said first optical information recording medium or said second optical information recording medium,

converts said reflected light to an electric signal and reads information from said electric signal,

converges the luminous flux that has passed through said internal area of the circumference or said outer area of the circumference of said lens onto the information recording surface of said first optical information recording medium, and

converges the luminous flux that has passed through said intermediate area of the circumference of said lens at a farther place than the information recording surface of said second optical information recording medium.

[Claim 12] An optical information recording medium writing/reading method of, by using the lens according to claim 3, converging luminous flux from a light source onto said first optical information recording medium or said second optical information recording medium, receiving reflected light from said first optical information recording medium or said second optical information recording medium, converting said reflected light to an electric signal and reading information from said electric signal,

characterized in that the luminous flux that has passed through said internal area of the circumference or said outer area of the circumference of said lens is allowed to converge onto the information recording surface of said first optical information recording medium, and

the luminous flux that has passed through said intermediate area of the circumference of said lens is allowed to converge onto the information recording surface of said second optical information recording medium.

[Brief Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a lens, an optical head apparatus, an optical information writing/reading apparatus and an optical information recording medium writing/reading method.

[0002]

[Background Art]

An optical memory technology using optical disks as high density, high capacity storage media with pit-shaped patterns, is widening its applicability to digital audio disks, video disks, document file disks and data files, etc.

[0003]

According to this optical memory technology, information is recorded onto and reproduced from an optical disk via micro-focused light beams with high accuracy and reliability. This writing/reading operation solely depends on its optical system.

[0004]

The basic functions of the optical head, which is a major component of the optical system, are broadly grouped under convergence that forms micro spots of diffraction limits, focus control and tracking control of the above-described optical system, and detection of pit signals. These functions are provided by combining various optical systems and photoelectric transfer detection systems according to the purpose and application.

[0005]

On the other hand, a high density, high capacity optical disk called "DVD" is put to practical use and stepping into a limelight as an information medium capable of handling large capacity information such as moving images in recent years. Compared to a compact disk (hereinafter, abbreviated as "CD"), which is a conventional optical disk, this DVD optical disk reduces a pit size on the information recording surface to increase recording density.

[0006]

Thus, the optical head apparatus for writing/reading a DVD optical disk is different from that for a CD in a wavelength of a light which determines a spot diameter and numerical aperture (hereinafter abbreviated as "NA")

of a converging lens. By the way, while the wavelength of the light of the CD is substantially 0.78 μm and NA is substantially 0.45, the wavelength of the light of the DVD optical disk is substantially 0.63 μm to 0.65 μm and NA is substantially 0.6.

[0007]

Thus, writing/reading two types of optical disks, CD and DVD optical disks using a single optical disk drive requires an optical head apparatus provided with two optical systems.

[0008]

On the other hand, in order to meet requirements of miniaturization, slimming and cost reduction of the optical head apparatus, the CD and DVD optical systems tend to share as many parts as possible with each other. For example, a method that two types of converging lens may be used for the DVD optical disk and for CD separately using the light source for DVD for both systems, a method that a converging lens may also be shared by making NA mechanically or optically changeable to provide greater NA for the DVD optical disk and smaller NA for the CD, or the like is adopted.

[0009]

Also, as disclosed in Japanese Patent Laid-Open No. 9-219035, a method of providing compatibility between

DVD and CD by optimizing a part of a converging lens which is optimized for DVD to the thickness of a CD base material in ring zone form is proposed. Of the above-described optical head apparatuses, the above-described method of Japanese Patent Laid-Open No. 9-219035 will be explained below with reference to the attached drawings.

[0010]

Figure 8 shows a configuration of an optical system of the optical head apparatus disclosed in Japanese Patent Laid-Open No. 9-219035. In the case of a general optical apparatus as illustrated here, an objective lens 23 is provided on an optical path between a disk 7 and optical detector 4 and a light source (semiconductor laser) 1 is placed on an optical path branched from a beam splitter 5. In the optical apparatus of the above-described Japanese Patent Laid-Open No. 9-219035, the objective lens 23 has a characteristic shape as shown in Figure 9(a) and (b).

[0011]

A special part (part which is different from a normal lens) is provided on one of the plane of incidence radiation of the objective lens 23. In the special part, a doughnut-shaped or ring-shaped intermediate area A2 having a smaller outer diameter than the overall effective diameter of the optical path area is provided. A central

area A1 is provided inside the intermediate area A2 and a peripheral area A3 is provided outside the intermediate area A2. The curvature of the above-described central area A1 and peripheral area A3 is optimized to make luminous flux converged onto the information recording surface of a thin DVD (digital video disk) 7a and the curvature of the above-described central area A2 is optimized to make luminous flux converged onto the information recording surface of a thick CD7b (compact disk). This central area A2 is sometimes provided to be divided in multiple areas.

[0012]

Then, it is desirable that the above-described optical detector 4 be designed so that the light from the far-axis area does not reach when information is reproduced from a thick disk, that is, the light reaches only the central area A1 and intermediate area A2 of the objective lens. Therefore, as indicated with dotted lines in Figure 9(b), when the thick CD7b is written or read, the light in the central area A1 and intermediate area A2 converges to the CD7b. In this case, even if the curvature of the central area A1 corresponding to the near-axis area is optimized to the thin DVD7a, the near-axis light close to the central axis of the lens passes, which causes less spherical aberration.

[0013]

Then, when the DVD7a is written or read, the light passes through the central area A1 and peripheral area A3 having the curvature optimized to the thin disk to form a focus on the information surface of the thin disk 7a.

[0014]

If the numerical aperture of the areas corresponding to the near-axis area and far-axis area of the above-described objective lens 23 is reduced to 0.4 or smaller, it is also possible to form a small spot for a thick disk and thereby form a spot of a size optimized to the CD disk.

[0015]

[Problems to be solved by the invention]

However, when a CD optical disk is written or read, the above-described conventional configuration has a problem that jitter (a value indicating variation of the time axis) increases considerably depending on the phase difference between the wavefront of luminous flux which passes the intermediate area A2 and the wavefront of luminous flux which passes the central area A1. That is, the problem is that because of lens manufacturing errors, constraints or improvement of the performance except jitter (e.g., degree of matching between the 0 level of

a focus error signal and minimum jitter focus position), it is difficult to secure a jitter value when the phase difference of the above-described wavefront of luminous flux which passes the intermediate area A2 with respect to the wavefront of luminous flux which passes the central area A1 changes from what previously conditioned for manufacture.

[0016]

These problems will be explained with reference to the attached drawings below. Figure 10 is, when NA of the objective lens 23 is 0.6 and NA inside the intermediate area A2 is 0.39, a graph illustrating a relationship between the phase of the intermediate area A2 with respect to the central area A1 and CD read jitter calculated using a simulation. The phase of the central area A2 is based on the phase of the central part of the objective lens 23 and the direction in which the phase of the intermediate area A2 delays from the phase of the central part is assumed to be positive.

[0017]

As apparent from Figure 3(b), when the thickness of the corresponding base material of the intermediate area A2 is 1.2 mm corresponding to the thickness of the CD base material, jitter may deteriorate drastically depending on the phase. For example, in Figure 3 (b),

t1.2 shows that jitter when the ring zone phase is 120 deg is bigger by about 10 points than jitter when the ring zone phase is 300 deg. That is, this indicates that, when the phase deviates from an ideal state because of manufacturing errors, etc., there is a problem that it may be difficult to secure CD read jitter.

[0018]

Next, the second problem is explained. The objective lens which has the conventional central ring zone has considerable level differences in perimeters of the ring zone. Since this makes it difficult to perform molding using a glass press lens with excellent temperature stability, a plastic lens has been generally used for molding and lens production and design of optical head, apparatus have been made taking the aberration changes by the temperature changes into consideration.

[0019]

The objective lens with the conventional central ring zone may have considerable level differences in both of or at least one of the inside and outside perimeters of the ring zone and even if an attempt is made to perform molding using a glass lens with high temperature stability, the molding is difficult from the standpoint of volume production or even if the molding is applicable to the shape, a large transition area (area in which the shape

of the section including level differences inevitably differs from the ideal shape from the standpoint of manufacturing of the molding die and could cause deterioration of a read signal, etc.), causing a problem that it is impossible to obtain sufficient characteristics.

[0020]

In view of the problems of the conventional optical head apparatus described above and it is an object of the present invention to provide lens which reduces changes of a jitter value depending on the variations of the phase difference with respect to the central area of the intermediate area and which makes the range of selection of the amount of phase broaden.

[0021]

It is another object of the present invention to provide lens which suppresses the amount of level differences produced and allows molding using a glass with excellent temperature stability.

[0022]

[Means to Solve the Problems]

The 1st aspect of the present invention (corresponding to Claim 1) is a convex lens for allowing luminous flux from a light source to converge to a first optical information recording medium having a predetermined

thickness and a second optical information recording medium thicker than the first optical information recording medium, characterized in that said convex lens comprises:

an internal area of the circumference close to a central axis of said luminous flux;

an outer area of the circumference far from said central axis; and

an intermediate area of the circumference located midway between said internal area of the circumference and said outer area of the circumference, and

said internal area of the circumference and said outer area of the circumference are the area where the luminous flux that has passed through said internal area of the circumference or said outer area of the circumference converges onto an information recording surface of said first optical information recording medium,

said intermediate area of the circumference is the area where the luminous flux that has passed through the intermediate area of the circumference converges at the further place than the information recording surface of said second optical information recording medium.

[0023]

The 2nd aspect of the present invention (corresponding to Claim 2) is a convex lens for allowing luminous flux

from a light source to converge to a first optical information recording medium having a predetermined thickness and a second optical information recording medium thicker than the first optical information recording medium, characterized in that said lens comprises:

an internal area of the circumference close to a central axis of said luminous flux;

an outer area of the circumference far from said central axis; and

an intermediate area of the circumference located midway between said internal area of the circumference and said outer area of the circumference, and

said internal area of the circumference, said outer area of the circumference and said intermediate area of the circumference are formed on a surface of said lens, the surface facing said first optical information recording medium or said second optical information recording medium.

[0024]

The 3rd aspect of the present invention (corresponding to Claim 3) is the lens according to the second aspect of the present invention, characterized in that the phase of the luminous flux that has passed through said intermediate area of the circumference is set to be shifted

by substantially 1 wavelength with respect to the phase of the luminous flux that has passed through said outer area of the circumference.

[0025]

The 4th aspect of the present invention (corresponding to Claim 4) is the lens according to any one of the 1st to the 3rd aspects of the present invention, characterized in that the luminous flux that passes through the innermost perimeter of said internal area of the circumference is set to make the phase shifted with respect to the luminous flux that passes through the outermost perimeter of said internal area of the circumference.

[0026]

The 5th aspect of the present invention (corresponding to Claim 5) is the lens according to the 4th aspect of the present invention, characterized in that the luminous flux that passes through the innermost perimeter of said intermediate area of the circumference is set to delay with respect to the luminous flux that passes through the outermost perimeter of said internal area of the circumference by an amount Δ that satisfies the following (Equation 1):

[0027]

[Equation 1]

$$240° + m \times 360° < \Delta < 360° + n \times 360°$$

m: Integer, n: integer more than or equal to m

The 6th aspect of the present invention (corresponding to Claim 6) is the lens according to the 5th aspect of the present invention, characterized in that said amount Δ is an amount that satisfies the following (Equation 2):

[0028]

[Equation 2]

$$270° + m \times 360° < \Delta < 330° + n \times 360°$$

m: Integer, n: integer more than or equal to m

The 7th aspect of the present invention (corresponding to Claim 7) is the lens according to any one of claims the 1st to the 6th aspects of the present invention, characterized in that when the numerical aperture (hereinafter referred to as "NA") of all luminous fluxes that have passed through said lens is assumed to be (a), said NA of the boundary between said internal area of the circumference and said intermediate area of the circumference is 0.6(a) to 0.8(a) and said NA of the boundary between said intermediate area of the circumference and said outer area of the circumference is 0.7(a) to 0.9(a).

[0029]

The 8th aspect of the present invention (corresponding to Claim 8) is the lens according to any one of the 1st ,

2^{nd}, 4^{th}, 5^{th}, 6^{th} and 7^{th} aspects of the present invention, characterized in that the thickness of said first optical information recording medium is substantially 0.6 mm and the thickness of said second optical information recording medium is substantially 1.2 mm, and

said intermediate area of the circumference is the area where the luminous flux that has passed through the intermediate area of the circumference converges at a farther place than the information recording surface of said second optical information recording medium, 2.2 mm at the farthest.

[0030]

The 9^{th} aspect of the present invention (corresponding to Claim 1) is an optical head apparatus, characterized by comprising the lens according to any one of the 1^{st} to the 8^{th} aspects of the present invention and a photoreception element that receives reflected light from said first optical information recording medium or said second optical information recording medium and converts said reflected light to an electric signal.

[0031]

The 10^{th} aspect of the present invention (corresponding to Claim 10) is an optical information recording medium writing/reading apparatus, characterized by comprising the optical head apparatus

according to the 9th aspect of the present invention and a circuit that distinguishes said first optical information recording medium from said second optical information recording medium, selectively reads information from said electric signal.

[0032]

The 11th aspect of the present invention (corresponding to Claim 11) is an optical information recording medium writing/reading apparatus, characterized by using said lens according to any one of the 1st, 2nd, 4th, 5th, 6th, 7th, and 8th aspects of the present invention, wherein the optical information recording medium writing/reading apparatus,

converges luminous flux from a light source onto said first optical information recording medium or said second optical information recording medium,

receives reflected light from said first optical information recording medium or said second optical information recording medium,

converts said reflected light to an electric signal and reads information from said electric signal,

converges the luminous flux that has passed through said internal area of the circumference or said outer area of the circumference of said lens onto the information

recording surface of said first optical information recording medium, and

converges the luminous flux that has passed through said intermediate area of the circumference of said lens at a farther place than the information recording surface of said second optical information recording medium.

[0033]

The 12^{th} aspect of the present invention (corresponding to Claim 12) is an optical information recording medium writing/reading method of, by using the lens according to the 3^{rd} aspect of the present invention, converging luminous flux from a light source onto said first optical information recording medium or said second optical information recording medium, receiving reflected light from said first optical information recording medium or said second optical information recording medium, converting said reflected light to an electric signal and reading information from said electric signal,

characterized in that the luminous flux that has passed through said internal area of the circumference or said outer area of the circumference of said lens is allowed to converge onto the information recording surface of said first optical information recording medium, and

the luminous flux that has passed through said intermediate area of the circumference of said lens is allowed to converge onto the information recording surface of said second optical information recording medium.

[0034]

[Preferred Embodiment of the Invention]

Embodiments of the present invention will be explained below.

[0035]

(Embodiment 1)

Figure 11 illustrates a configuration of an optical system of an optical head apparatus according to Embodiment 1 of the present invention. The configuration shown in the same drawing is the same as the configuration of the optical head apparatus of the conventional example except the objective lens 20 and the same components as those in Figure 8 are assigned the same reference numerals and explanations thereof will be omitted. Figure 1 shows an objective lens 20 of Embodiment 1 of the present invention. A optical detector 4 in Figure 11 is applicable as the photoreception element of the optical head apparatus according to claim 9 of the present invention and a read signal circuit 10 in Figure 11 is applicable as the circuit of the optical information writing/reading

apparatus according to claim 10 of the present invention. The optical detector 4 is the means of receiving reflected light from the optical disk 7 and converting the reflected light to an electric signal and the read signal circuit 10 is a circuit that distinguishes the type of the optical disk 7 and selectively reads information from the electric signal.

[0036]

What the objective lens 20 according to Embodiment 1 of the present invention shown in Figure 1 differs from the objective lens 23 shown in the convention example is the thickness of the corresponding base material of the intermediate area A2. In the conventional example, the thickness of the corresponding base material of the intermediate area A2 is optimized to a thick disk, that is, a CD with a base material thickness of 1.2 mm in this case, while in an intermediate area A2 of the objective lens 20 according to Embodiment 1 of the present invention, it is optimized to a base material thicker than the CD, that is, 1.6 mm. That is, the intermediate area A2 is set to converge the luminous flux that has passed the intermediate area A2 onto a farther place than an information recording surface of a CD. Accordingly, curvature radius, non-spherical coefficient and so on are to be changed from the conventional ones so that the

intermediate area A2 of the objective lens 20 can be optimized to a base material thicker than the CD.

[0037]

Figure 2 shows wavefront aberration when the DVD7a with a base material thickness of 0.6 mm and CD7b with a base material thickness of 1.2 mm are read. The section of the intermediate area A2 is optimized to the base material thickness of 1.6 mm, and therefore aberration is provided also when the CD7b with a base material thickness of 1.2 mm is read.

[0038]

Further, Figure 3(b) shows the variation of CD read jitter by the phase shift of the part of the intermediate area A2 that contacts the central area A1 with respect to the central part of the lens when the corresponding base material thickness of the intermediate area A2 is changed from 1.2 mm to 1.8 mm.

[0039]

From this, it is observed to be possible to reduce jitter variations due to phase jitter of the intermediate area A2 by changing the corresponding base material thickness of the central area A2 from 1.2 mm to 1.6 mm. For example, when the ring zone phase is 120 deg in Figure 3 (b)jitter is apparently reduced as the corresponding base material becomes thicker: from t1.2 to t1.4, t1.6,

further, t1.8 at the thickest. And, according to this simulation result, when the corresponding base material thickness of the central area A2 is 1.6 mm, it is also observed that when the pass of the wavefront with respect of the center area A1 is delayed by the amount of phase of 300 degrees, that is advanced by 60 degrees, CD read jitter can be reduced most.

[0040]

Thus, in the embodiment of the present invention, the phase of luminous flux was set to advance by 300 degrees (-60 degrees) with respect to the central part of the lens of the objective lens 20, after setting the corresponding base material thickness of the central area A2 to 1.6 mm. Thus, setting the corresponding base material thickness of the central area A2 to 1.6 mm shown in the embodiment of the present invention makes it possible to reduce deterioration of jitter due to phase shifts associated with manufacturing errors, etc, instead of setting the corresponding base material thickness of the central area A2 to 1.2 mm as in the case of the conventional example.

[0041]

(Embodiment 2)

Figure 12 illustrates a configuration of an optical system of an optical head apparatus according to

Embodiment 2 of the present invention. The configuration shown in the same drawing is the same as the configuration of the optical head apparatus shown in Embodiment 1 of the present invention except the objective lens 21 and the same components as those in Figure 8 or 11 are assigned the same reference numerals and explanations thereof will be omitted. Figure 4 shows the objective lens 21 according to Embodiment 2 of the present invention.

[0042]

As shown in Figure 4, what the objective lens 21 according to Embodiment 2 of the present invention differs from the objective lens 20 shown in Embodiment 1 is that the surface on which the intermediate area A2 is set is a second surface (optical disc surface) and the thickness of the corresponding base material of the intermediate area A2. In Embodiment 1, the intermediate area A2 is set on the side of the first surface, while in this Embodiment, setting the intermediate area A2 on the side of the second surface with smaller curvature makes it possible to reduce the transition area necessary to perform glass press molding (area in which the shape of the area including level differences inevitably differs from an ideal shape for reasons related to manufacturing of molding dies and could cause deterioration of a read signal, etc.).

[0043]

Furthermore, the corresponding base material thickness of the intermediate area A2 is optimized to a thick disk, that is, 1.6 mm in Embodiment 1, while in this embodiment, the corresponding base material thickness of the intermediate area A2 is optimized to an even thicker base material of 1.8 mm and there is no level difference between the intermediate area A2 and peripheral area A3. Figure 5 illustrates wavefront aberration when a DVD7a with a base material thickness of 0.6 mm and CD7b with a base material thickness of 1.2 mm are read using the objective lens 21.

[0044]

A general method of molding an objective lens is to perform injection molding on a plastic material or apply thermo-pressing to a plastic material or glass material. Since processing is performed using metal molds in all cases, the ease of processing of metal molds and the life of metal molds are important factors that affect the cost of the lens itself. From the standpoint of processing of metal molds, level differences on a lens need to be processed using sharp cutting tools, and are therefore not desirable. Therefore, it is desirable that either the inside perimeter or the outside perimeter of the intermediate area A2 be contiguous on the boundary to

the central area A1 or peripheral area A3 without level differences.

[0045]

Furthermore, when the shape of the cutting tool is taken into account, even if the intermediate area A1 and central area A2 are contiguous, the bending angle of the metal mold surface is 180 degrees or less, which inevitably requires processing with a sharp cutting tool. For this reason, it is further desirable that the contiguous plane be outside the intermediate area A2, that is, that the boundary with the peripheral area A3 be contiguous. According to our design, it has been found that by setting the corresponding base material thickness of the intermediate area A2 to 1.8 mm, NA of the outside of the intermediate area A2 to 0.45 and NA of the inside to 0.39, it is possible to eliminate level differences between the intermediate area A2 and peripheral area A3 and change the phase in the center of the lens to close to ideal 300 degrees because of jitter reduction during a CD read.

[0046]

This design requires a transition area to be provided on the boundary between the intermediate area A2 and central area A1, but it is a level that will not affect the quality of a read signal and it is now possible to

manufacture metal molds capable of molding glass materials.

[0047]

Using the art of this Embodiment 2 of the present invention, it makes possible to apply a press working method for glass materials and construct a high precision, high reliability system required for a DVD system in particular.

[0048]

(Embodiment 3)

Figure 13 illustrates a configuration of an optical system of an optical head apparatus according to Embodiment 3 of the present invention. The configuration shown in the same drawing is the same as the configuration of the optical head apparatus shown in Embodiment 1 of the present invention except the objective lens 22 and the same components as those in Figure 8 or 11 are assigned the same reference numerals and explanations thereof will be omitted. Figure 6 shows the objective lens 22 according to Embodiment 3 of the present invention.

[0049]

Here, what the objective lens 22 according to Embodiment 3 of the present invention differs from the objective lens 21 shown in Embodiment 2 is that the phase of the internal area of the circumference A1 is shifted

from the peripheral area A3 by 1 wavelength (DVD wavelength) with respect to the wavelength of the DVD and that the thickness of the base material of the intermediate area A2 is set to 1.2 mm and that outside NA of the intermediate area A2 is set to 0.46.

[0050]

In Embodiment 2, the corresponding base material thickness of the intermediate area A2 is optimized to a thick desk, that is, a base material thickness of 1.8 mm in this case, while in this embodiment, the corresponding base material thickness of the intermediate area A2 is optimized to a base material thickness of 1.2 mm which is the base material thickness of the CD itself. Figure 7 illustrates wavefront aberration when a DVD7a with a base material thickness of 0.6 mm and CD7b with a base material thickness of 1.2 mm are read using the objective lens 22.

[0051]

Since the intermediate area A2 is optimized to a base material thickness of 1.2 mm, no aberration is produced when a CD7b with a base material thickness of 1.2 mm is read. Furthermore, in the embodiment, there is almost no level difference on the boundary between the intermediate area A2 and peripheral area A3, and moreover the level difference between the central area A1 and

intermediate area A2 can be made smaller than Embodiment 2 of the present invention.

[0052]

A general method of molding an objective lens is to perform injection molding on a plastic material or apply thermo-pressing to a plastic material or glass material. Since processing is performed using metal molds in all cases, the ease of processing of metal molds and the life of metal molds are important factors that affect the cost of the lens itself.

[0053]

From the standpoint of processing of metal molds, level differences on a lens need to be processed using sharp cutting tools, and are therefore not desirable. Therefore, it is desirable that either the inside perimeter or the outside perimeter of the intermediate area A2 be contiguous on the boundary to the central area A1 or peripheral area A3 without level differences. Since our simulation has demonstrated that it is possible to reduce CD jitter by changing the intermediate area A2 from 240 degrees to 300 degrees (from -120 degrees to -60 degrees) when the corresponding base material thickness is 1.2 mm, it has been proven that it is possible to eliminate a level difference between the intermediate area A2 and peripheral area A3 by shifting the wavefront

of the central area A1 by 1 phase with the wavelength (650 nm) of a DVD with respect to the wavefront of the peripheral area A1 and further set the phase difference on the boundary between the intermediate area A2 and central area A1 to close to ideal 300 degrees (-60 degrees) resulting from a jitter reduction during a CD read by setting NA outside the intermediate area A2 to 0.46 and thereby reduce level differences in lens molding. This makes it possible to further reduce the transition area of the boundary between the central area A1 and intermediate area A2.

[0054]

Using this art of the Embodiment 3 of the present invention makes it possible to apply a press working method for glass materials and construct a high precision, high reliability system required for a DVD system in particular.

[0055]

The Embodiment 1 of the present invention obtains an outstanding effect of reducing deterioration of CD read jitter due to a phase shift of the internal area of the circumference by setting the corresponding base material thickness of the intermediate area to a thick disk, that is, 1.6 mm thicker than the CD base material thickness of 1.2 mm, thereby setting the amount of phase

to an appropriate amount, optimizing the central area and intermediate area combined to the CD.

[0056]

The Embodiment 2 of the present invention obtains an outstanding effect of reducing deterioration of CD read jitter due to a phase shift of the intermediate area by setting the corresponding base material thickness of the intermediate area to a thick disk, that is, 1.8 mm thicker than the CD base material thickness of 1.2 mm, eliminating level differences of the intermediate area and peripheral area, optimizing the central area and intermediate area combined to the CD, and also an outstanding effect of facilitating the manufacturing of lens processing metal molds. Especially, the Embodiment 2 of the present invention allows manufacturing using a glass material, making it possible to provide high precision and high reliability required for a DVD system, etc.

[0057]

The Embodiment 3 of the present invention shifts the wavefront of the central area by 1 wavelength (DVD wavelength) from the peripheral area, and can thereby set the amount of phase difference between the central area and intermediate area to an appropriate amount and reduce level differences among areas to a very small level,

further facilitating manufacturing of DVD/CD compatible lenses that can be subjected to glass pressing.

[0058]

[Effect of the Invention]

As apparent from the foregoing explanations, the present invention can reduce deterioration of read jitter of an optical disk with a large base material thickness due to differences such as manufacturing errors in the amount of phase shift of the internal area of the circumference with respect to the central area of an objective lens, in the objective lens which produces the optical disk with a small base material thickness mainly in the central area and the peripheral area, the optical disk with a large base material thickness mainly in the central area and the peripheral area, divided in the central area, the peripheral area, and the intermediate area, respectively. The present invention has advantages of being able to facilitate the processing of an objective lens processing metal mold, reduce lens costs by extending the life of the metal mold or select glass as a material of the lens and thereby implement a system with higher accuracy and higher reliability.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1]

Figure 1(a) and (b) illustrate an objective lens according to Embodiment 1 of the present invention;

[Fig. 2]

Figure 2 illustrates a wavefront on a disk during reading of DVD or CD according to the Embodiment 1.

[Fig. 3]

Figure 3(a) and (b) illustrate a thickness of a base material corresponding to an intermediate area of the objective lens of Embodiment 1, a phase relationship between the intermediate area and central area and a relationship of a CD read signal with jitter.

[Fig. 4]

Figure 4(a) and (b) illustrate an objective lens according to Embodiment 2 of the present invention.

[Fig. 5]

Figure 5 illustrates a wavefront on the disk during reading of the DVD or CD according to the Embodiment 2.

[Fig. 6]

Figure 6(a) and (b) illustrate an objective lens according to Embodiment 3 of the present invention.

[Fig. 7]

Figure 7 illustrates a wavefront on the disk during reading of the DVD or CD according to Embodiment 3.

[Fig. 8]

Figure 8 illustrates a configuration of an optical system of a conventional optical head apparatus.

[Fig. 9]

Figure 9 illustrates an objective lens of the conventional optical head apparatus.

[Fig. 10]

Figure 10 illustrates the thickness of a corresponding base material of the intermediate area and a phase relationship between the intermediate area and central area of the conventional example.

[Fig. 11]

Figure 11 illustrates a configuration of an optical system of an optical head apparatus according to Embodiment 1 of the present invention.

[Fig. 12]

Figure 12 illustrates a configuration of an optical system of an optical head apparatus according to Embodiment 2 of the present invention.

[Fig. 13]

Figure 13 illustrates a configuration of an optical system of an optical head apparatus according to Embodiment 3 of the present invention.

[Description of Symbols]

1 Semiconductor laser

2 Optical beam

3 Collimator lens

4 Photo detector

5 Beam splitter

7a Optical disk (DVD)

7b Optical disk (CD)

20 Objective lens according to Embodiment 1 of the present invention

21 Objective lens according to Embodiment 2 of the present invention

22 Objective lens according to Embodiment 3 of the present invention

23 Objective lens of conventional optical head apparatus